MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2015/2016

EME2146 – APPLIED THERMODYNAMICS

(ME)

11 MARCH 2016
9.00 a.m - 11.00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of six pages (including the cover page) with four questions and an Appendix.
2. Answer ALL four questions.
3. Each question carries 25 marks and the distribution of the marks for each question is given in brackets [ ].
4. Write all your answers in the answer booklet provided.
5. A property table booklet is provided for your reference.

Question 1

A vessel contains non-reacting mixtures at 100 kPa and 70 °C. The mixture consists of 6 moles of nitrogen gas (N_2), 2 moles of oxygen gas (O_2), 1 mole of carbon dioxide gas (CO_2), and 1 mole of water vapor (H_2O).

Substance	N_2	O_2	CO_2	H_2O
Molecular weight (g/mol)	28	32	44	18

Assuming ideal gas behavior of the gaseous mixtures and taking the universal gas constant, $R = 8.314$ J/mol·K, determine

a. the mole fraction of each component,

[4 marks]

b. the mass of each component,

[4 marks]

c. the mass fraction of each component,

[4 marks]

d. the volume of the vessel,

[3 marks]

e. the absolute humidity of the mixture,

[3 marks]

f. the relative humidity of the mixture, and

[4 marks]

g. the dew point temperature of the mixture if the total pressure is kept constant.

[3 marks]

Continued...

Question 2

Propylene fuel (C_3H_6) at 25°C is burned with 30 percent excess air during a steady flow combustion process. The combustion process is complete and the product pressure is 100 kPa. Air enters the combustion chamber at 25°C and the products leave the chamber at 517°C.

a. Write the balanced combustion equation.

[4 marks]

b. Determine the air-fuel ratio.

[3 marks]

c. Determine the dew-point temperature of the products.

[3 marks]

d. Calculate the heat transfer, in kJ/kmol fuel, during this combustion.

[12 marks]

e. Calculate the required mass flow rate of the fuel, when the combustion process produces a heat transfer rate of 1500kW.

[3 marks]

Continued...

Question 3

A steam power plant operates on the ideal reheat Rankine cycle. Steam enters the high pressure turbine at 12.5 MPa and 450°C and leaves at 2.0 MPa. Steam then enters the low pressure turbine at 2.0 MPa and 450°C, and the condenser at 50 kPa.

a. Determine the turbine output, in kJ/kg and the thermal efficiency of the cycle.

[17 marks]

b. Assuming isentropic efficiencies of 100 percent for pump and 85 percent for both the turbines, determine the turbine output, in kJ/kg.

[5 marks]

c. Show the cycle in (b) on a $T - s$ diagram with respect to saturation lines.

[3 marks]

Continued...

Question 4

A very large frictionless piston cylinder system contains 1000 mol of a gaseous pure substance. The force, $F = 3250$ kN is applied constantly on the piston along the direction of the displacement to compress the gas as shown in Figure Q4. The piston moves slowly and displaces 2 m from its initial position. The initial and final pressures are $p_1 = 400$ kPa and $p_2 = 2.00$ MPa while the temperatures, $T_1 = 200$ K is maintained constant throughout the compression process.

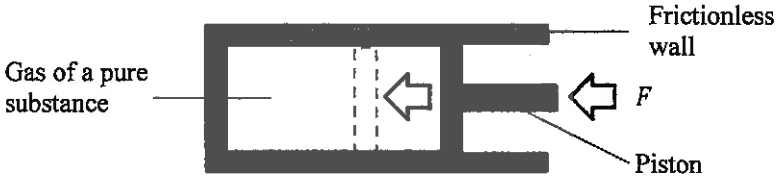

Figure Q4

The equation of state of the substance is expressed by relating the compressibility factor, Z, to the reduced pressure, p_r and reduced temperature, T_r:

$$Z = 1 + \frac{1000}{{p_r}^2} - \left[\frac{2p_r}{{T_r}^3} + \frac{20}{{T_r}^2} + \frac{200}{p_r T_r} + \frac{1000}{{p_r}^2}\right] e^{-\frac{p_r}{5T_r}}$$

The universal gas constant and the specific heat ratio of the substance are $R = 8.314$ J/mol·K and $\gamma = 1.4$ respectively. The critical pressure, p_c and critical temperature, T_c of the substance are 4.00 MPa and 100 K respectively.

a. From the equation of state, show that at very high temperature, $T_r \gg 1$, the substance behaves as an ideal gas.

[4 marks]

b. Express the isothermal enthalpy departure in terms of reduced pressure and reduced temperature.

[8 marks]

c. Calculate the amount of heat transferred.

[13 marks]

Continued...

APPENDIX

A1. Clayperon Relation:

$$\frac{dp_{sat}}{dT} = \frac{s_{fg}}{v_{fg}} = \frac{h_{fg}}{Tv_{fg}}$$

A2. Maxwell Relations:

$$\left(\frac{\partial T}{\partial v}\right)_s = -\left(\frac{\partial p}{\partial s}\right)_v ; \quad \left(\frac{\partial T}{\partial p}\right)_s = \left(\frac{\partial v}{\partial s}\right)_p$$
$$\left(\frac{\partial v}{\partial T}\right)_p = -\left(\frac{\partial s}{\partial p}\right)_T ; \quad \left(\frac{\partial p}{\partial T}\right)_v = \left(\frac{\partial s}{\partial v}\right)_T$$

A3. Change of internal energy, enthalpy, and entropy:

$$u_2 - u_1 = \int_{T_1}^{T_2} c_v dT + \int_{v_1}^{v_2} \left[T\left(\frac{\partial p}{\partial T}\right)_v - p\right] dv$$
$$h_2 - h_1 = \int_{T_1}^{T_2} c_p dT + \int_{p_1}^{p_2} \left[v - T\left(\frac{\partial v}{\partial T}\right)_p\right] dp$$
$$s_2 - s_1 = \int_{T_1}^{T_2} \frac{c_v}{T} dT + \int_{v_1}^{v_2} \left(\frac{\partial p}{\partial T}\right)_v dv = \int_{T_1}^{T_2} \frac{c_p}{T} dT - \int_{p_1}^{p_2} \left(\frac{\partial v}{\partial T}\right)_p dp$$

A4. Enthalpy, entropy and internal energy of departure:

$$\frac{(h^* - h)_T}{RT_c} = \int_0^{p_r} \left[T_r{}^2 \left(\frac{\partial Z}{\partial T_r}\right)_p\right] \frac{dp_r}{p_r}$$
$$\frac{(s^* - s)_T}{R} = \int_0^{p_r} \left[Z - 1 + T_r \left(\frac{\partial Z}{\partial T_r}\right)_p\right] \frac{dp_r}{p_r}$$
$$\frac{(u^* - u)_T}{RT_c} = \frac{(h^* - h)_T}{RT_c} + T_r(Z - 1)$$

A5. Specific heats difference:

$$c_p - c_v = \frac{Tv\alpha_p{}^2}{\beta_T}$$

A6. Some useful calculus relations:

Integration by parts: $\int \spadesuit(\blacklozenge)\clubsuit(\blacklozenge)\, d\blacklozenge = \spadesuit(\blacklozenge) \int \clubsuit(\blacklozenge)\, d\blacklozenge - \int \left[\left(\int \clubsuit(\blacklozenge)\, d\blacklozenge\right) \spadesuit'(\blacklozenge)\right] d\blacklozenge$

Integration of quotient: $\int \frac{\clubsuit'(\blacklozenge)}{\clubsuit(\blacklozenge)} d\blacklozenge = \ln[\clubsuit(\blacklozenge)]$

Differentiation of product $(\spadesuit(\blacklozenge)\clubsuit(\blacklozenge))' = \spadesuit'(\blacklozenge)\clubsuit(\blacklozenge) + \spadesuit(\blacklozenge)\clubsuit'(\blacklozenge)$

Differentiation of quotient: $\left(\frac{\spadesuit(\blacklozenge)}{\clubsuit(\blacklozenge)}\right)' = \frac{\spadesuit'(\blacklozenge)\clubsuit(\blacklozenge) - \spadesuit(\blacklozenge)\clubsuit'(\blacklozenge)}{[\clubsuit(\blacklozenge)]^2}$

Cyclic relation: $\left(\frac{\partial \spadesuit}{\partial \clubsuit}\right)_\blacklozenge \left(\frac{\partial \clubsuit}{\partial \blacklozenge}\right)_\spadesuit \left(\frac{\partial \blacklozenge}{\partial \spadesuit}\right)_\clubsuit = -1$

End of Paper